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(21) International Application Number: PCT/GB97/02690 (22) International Filing Date: 29 September 1997 (29.09.97) (30) Priority Data: 9620190.0 27 September 1996 (27.09.96) GB (71) Applicant (for all designated States except US): FLYING NULL LIMITED [GB/GB]; Harston Mill, Harston, Cambridge CB2 5NH (GB). (72) Inventors; and (75) Inventors/Applicants (for US only): CROSSFIELD, Michael, David [GB/GB]; Perme Drift, Burton End, West Wickham, Cambridge CB1 6SD (GB). COGGILL, Christopher, John [GB/GB]; 55 High Street, West Wratting, Cambridge CB1 5LU (GB). (74) Agents: ABRAMS, Michael, John et al.; Haseltine Lake & Co., Imperial House, 15-19 Kingsway, London WC2B 6UD (GB).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
(54) Title: MULTI-LAYER MAGNETIC TAG		
(57) Abstract		
<p>A magnetic marker or tag is disclosed which comprises (a) a first magnetic material characterised by high permeability, low coercivity and a non-linear B-H characteristic; and (b) a second magnetic material which is capable of being permanently magnetised, said first and second magnetic materials being superimposed one on the other and advantageously being substantially coterminous. The second magnetic material is preferably of medium coercivity. Selected regions of said second magnetic material can carry magnetisation such as to magnetically divide the first magnetic material into a series of magnetically discrete zones, the length of said magnetically discrete zones and/or the lengths of said magnetised regions ("gaps") of said second material constituting elements of a code.</p>		

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MULTI-LAYER MAGNETIC TAG

Background To The Invention

5 This invention relates to magnetic tags and, more particularly but not exclusively, is concerned with tags which can be encoded with data.

10 In previous patent applications, notably in WO96/31790 and WO97/04338, we have described remote identification tags which may be interrogated using alternating and/or static magnetic fields. In response to interrogation the tags emit magnetic signals which may be detected in suitable receiving equipment. Such tags have many
15 applications in areas such as article identification, security and access control.

Certain of the tags described in WO96/31790 contain elements of high permeability, low coercivity, "soft"
20 magnetic alloy in the form of a strip, wire or thin film, overlaid with a medium coercivity magnetic layer. The magnetic signal or "signature" generated by the high permeability element in response to interrogation is determined by the magnetisation pattern stored in
25 the medium coercivity "coding" layer, and the characteristics of the high permeability element.

In practical implementations tag coding can for example be carried out during tag manufacture by contact- or
30 near contact-recording the appropriate magnetic pattern onto a continuous coding layer using an array of permanent magnets. This method is particularly suitable for producing many tags with the same code.

35 Another method, which is suitable for manufacturing tags whose code will never require change, is to place

suitably-magnetised pieces of coding material at appropriate positions on the high permeability material.

- 5 Yet another method is to place un-magnetised pieces of medium coercivity material in an appropriate pattern using e.g. a thermal transfer process, and then to bulk-magnetise the entire structure.
- 10 A very convenient arrangement uses a magnetic recording head of the type well-known for recording information onto magnetic tape. With this arrangement, tags manufactured with a uniform un-magnetised coding layer can have patterns individually coded at the
- 15 point-of-issue. This is extremely useful for applications such as airline baggage tagging, where individual tag details (passenger name etc.) are not known in advance of issue.
- 20 WO97/04338 discloses a magnetic marker or tag, which comprises (a) a first magnetic material characterised by high permeability, low coercivity and a non-linear B-H characteristic; and (b) a second magnetic material which is capable of being permanently magnetised,
- 25 characterised in that said second magnetic material is magnetised with a non-uniform field pattern.

Summary of The Invention

- 30 The present application relates to magnetic tags whose construction is such that, by means of relatively simple magnetic recording, it is possible to generate recorded patterns in parts of the tag which are such as to isolate areas of a tag (made from a continuous layer
- 35 of soft magnetic material) such that the areas behave magnetically as if they were physically separate. It

also describes how data may be encoded into such a tag using variations in size and/or spacing of the isolated regions.

- 5 More particularly, according to one aspect of the present invention, there is provided a magnetic marker or tag which comprises (a) a first magnetic material characterised by high permeability, low coercivity and a non-linear B-H characteristic; and (b) a second
- 10 magnetic material which is capable of being permanently magnetised, said first and second magnetic materials being superimposed one on the other. Advantageously, the two magnetic materials are substantially coterminous. Such a tag can be encoded with
- 15 information by magnetising selected regions of the second magnetic material; the magnetised regions nullify the properties of the first magnetic material with which they are in contact, thereby effectively dividing the soft (first) magnetic material into a
- 20 series of magnetically discrete zones even though in physical terms the material is continuous. For convenience, magnetised regions of the second magnetic material are referred to herein as "gaps" since they serve to synthesise magnetic gaps in the first magnetic
- 25 material with which they are in contact.

Preferably, the second magnetic material is a material of medium coercivity.

- 30 As will be explained below, the preferred nature of the magnetisation depends upon the physical size of the gap.

- According to another aspect of the present invention,
- 35 there is provided a magnetic marker or tag which comprises (a) a first magnetic material characterised

by high permeability, low coercivity and a non-linear B-H characteristic; and (b) a second magnetic material which is capable of being permanently magnetised, said first and second magnetic materials being superimposed
5 one on the other, wherein selected regions of said second magnetic material carry magnetisation such as to magnetically divide the first magnetic material into a series of magnetically discrete zones, the length of said magnetically discrete zones and/or the lengths of
10 said magnetised regions ("gaps") of said second material constituting elements of a code.

The magnetically discrete zones of said first magnetic material ("active regions") and the lengths of said
15 magnetised regions ("gaps") of said second material constituting elements of a code can be thought of as "magnetic codons" since they are used in the invention to generate coded information in the tag. A suitable encryption key is required for writing and/or reading
20 the information; this is preferably as simple as possible, and can in any event be achieved by conventional means. A simple encryption system is described, by way of example, later in this document.

25 In one embodiment, the lengths of the magnetically discrete zones in said first magnetic material ("active regions") are constant whereas the lengths of the magnetised regions ("gaps") of said second material are varied to provide encoding of data. Other arrangements
30 - e.g. using different lengths for the active regions as well as, or instead of, different lengths for the gaps - may be adopted if desired.

The invention is thus able to provide magnetically
35 recorded patterns on a tag made from a layer of soft magnetic material overlaid by a layer of medium

coercivity magnetic material.

Numerous materials are commercially available which can be satisfactorily be used in this invention. For
5 example, one suitable material for use as the first, soft magnetic material is the thin-film material supplied by IST of Belgium under the trade name "Atalante". This is a sputtered amorphous alloy with a thickness of about 1 μm supported on a PET backing.
10 The film has a typical intrinsic permeability of 10^5 and a low frequency coercivity of a few A/m.

Suitable coding materials - i.e. materials for use as the second magnetic material - are finely-divided
15 ferromagnetic oxides with coercivities in the range 100 to 6000 oersted. Suitable materials are available commercially from many suppliers, e.g. BASF (Germany), Kurtz (Germany) and TDK (Japan), and are generally used for the manufacture of magnetic recording media.

20 The simplest format of multi-bit tag (also termed label) capable of being read by a Flying Null reader as described in WO96/31790 consists of an array of physically separate pieces of magnetic material, the
25 information being encoded by the sizes of the metal elements and/or the gaps between them.

In such a design the minimum length of element which can be reliably detected is determined by the details
30 of the reader, the intrinsic properties of the magnetic material, and the shape of the element. For example, for simple labels made from Atalante film thin, the critical length of 3 mm wide material for detection in a 2nd harmonic detector of the type described in GB
35 9506909.2 is currently around 5 mm. Lengths of half this dimension produce negligible output. This arises

from the shape factor of the element, which reduces the extrinsic permeability of the material from about 10^5 for an element of infinite length, to around 5000 for a 5 mm length, and to less than half this for a 2.5 mm length.

For labels made from a continuous layer of thin film, it is necessary to make the spaces between the regions where material is required to be detected appear to the reader to be magnetically inactive. This may be done by suitably-magnetising the recording layer overlaying these regions.

If the regions are short, i.e. less than half the minimum length for an active region, then it is sufficient to apply a simple uniform magnetisation over them in order to render them essentially inactive. Such a magnetisation would prevent the leading edge of the region from responding to interrogation by the null of the reading system at the same spatial point as the trailing edge of the immediately adjacent active region. Furthermore, we have found that when the null moves to a point where the net fields over the pre-magnetised region is zero, the length of the region would make the signal generated negligible.

However, for regions which are comparable with or greater than the minimum length for an active region, a simple uniform magnetisation is generally unsatisfactory. This is because a magnetised region will become active when the null of the reader is at a point where the net field over the region is zero, and at this point the region will generate a signal which may overlay that from an active region, and corrupt the intended signal.

A universally-suitable recorded pattern is generally a simple repetitive sequence which reverses in polarity with a spatial frequency such that North and South poles of the pattern are separated by, at most, half the minimum active length for the soft magnetic material. This ensures that the regions of material overlaid by the pattern are magnetically segregated into lengths incapable of generating a significant signal by virtue of their low effective permeability.

10

For labels made as described above and using 3 mm wide strips of Atalante film overlaid with a medium coercivity recording layer, the minimum length for an active segment is typically 5 mm. To render regions of any length inactive the spatial wavelength of the recorded pattern therefore needs to be less than around 5 mm, and preferably less than 2.5 mm.

For labels made from Vacuumschmeltze type 6025 amorphous strip 1 mm wide and 15 μ m thick the minimum effective active element length in a reader such as described in PCT/GB96/00823 is around 10 mm, and the spatial wavelength of the recorded pattern needs to be less than 10 mm, and preferably less than 5 mm, for good attenuation of signals from the underlying region.

Such magnetisation patterns can be created using closely-spaced arrays of narrow permanent magnets. Another technique is to deposit the recording layer in segments which are narrower and more closely spaced than the critical dimensions described above, and then to magnetise them uniformly in those regions of the tag which are required to be inactive. Yet another alternative is to use a conventional contact magnetic recording process of the type widely used for recording information onto magnetic tape. Such processes can

easily achieve spatial resolutions of a few μm , and thus by using such heads it is also easy to sharply define the end conditions on the inactive segments by adjusting the phase of the recorded signal. This can
5 be useful in defining precise spatial end points of blocks. For example a sinusoidal bias pattern can be set to start and end at the 90 degree phase points of the sine wave, rather than zero phase, giving very rapid rise of field at the start and end of the segment
10 which is intended to be inactive. It is also simple to programme patterns where the residual bias over the active regions caused by the fields from the ends of the magnetised region are either of uniform polarity, or reverse in polarity from one end to the other.

15

Examples of suitable patterns for the inactive regions of multi-bit data tags are indicated in the Figures below. In all cases the patterns include "guard bands" at each end. These inactive regions ensure that the
20 active regions in a tag structure are all in similar local magnetic environments, improving consistency of segment lengths as measured by the reader system.

Exemplary Coding Schemes for Multi-bit Flying Null Tags

25

Tags constructed as described above are capable of being encoded with information using a variety of schemes. One of the simplest is described in one of our earlier applications. This uses the presence of an
30 active region to denote a digital "1", and an inactive region to denote a digital "0", the spacing between regions being constant along the tag. Since inactive regions are, by definition, not detected by the tag reader it is also necessary to add active regions at
35 both ends of the tag, to indicate to the reader when the data has started and ended. This enables the

storage of a character by using a binary representation. For example, a decimal "6" could be represented by 11101, 110 being the binary representation of 6, and the leading and trailing "1"s indicating the start and end of the data. This scheme is very easy to apply, and particularly suitable for tags with only a few bits data capacity. For higher data capacity tags, however, this scheme is less attractive. A particular drawback is that as data words get longer, the codes can contain long runs of successive "0"s, and this causes problems in decoding. These problems include deciding when the end of a tag has been reached, and in accommodating signal width variations caused by variations in tag speed with motion relative to the reader.

Robust coding schemes for high capacity tags are those which do not generate long runs of successive "0"s and have inherent embedded tag speed information. It is also very convenient from an implementation viewpoint if tags of a given data capacity are all the same physical length.

A general approach which enables coding schemes which can meet all these criteria is based on encoding information by varying the lengths of the inactive regions (gaps) between fixed length active regions.

A practical example of one such coding scheme will now be described. In this scheme a character block is made up from 4 active regions and 3 inactive regions. The active regions are all of constant length, and the first and last are fixed in position. The positions of the middle two active regions are variable, and are defined by a scheme which assigns one of four possible lengths to each of the three inactive regions in the

-10-

block, with the constraint that the total physical length of the block remains constant. A typical set of gap sizes is 1.5, 3.5, 5.5 and 7.5 mm, using 5 mm active regions, with the constraint that three gaps
5 defining a character sum to 12.5 mm. This gives twelve possible variations, which can be related to characters as follows:

10	GAP1	GAP2	GAP3	CHARACTER
	1.5	3.5	7.5	0
	1.5	5.5	5.5	1
	1.5	7.5	3.5	2
	3.5	1.5	7.5	3
15	3.5	3.5	5.5	4
	7.5	3.5	1.5	5
	5.5	5.5	1.5	6
	3.5	7.5	1.5	7
	7.5	1.5	3.5	8
20	5.5	3.5	3.5	9
	3.5	5.5	3.5	*
	5.5	1.5	5.5	#

25 The characters 0-4, when read in the reverse direction, correspond to the characters 5-9, while the * and # symbols are palindromes. Using this coding scheme, the reading direction of the tag can conveniently be
determined by using the * or # as start or stop
30 characters. For greater code security, a checksum

character in modulo-5 format can be placed centrally in a number containing an even number of characters. This gives information both on the direction (because reverse values will read as 5-9) and the integrity of the data.

Information on the speed of the tag can be extracted by the tag reading apparatus by timing the occurrences of every third active region. These regions occur at character block spacings, and are preferably uniformly spaced every 27.5 mm along the tag.

Of course, other values of gaps sizes and active element lengths may be used, and the same principles can be applied to schemes with different numbers of gaps and gap size steps. For example, a simple extension to the scheme described is to create a fifth step size option of 9.5 mm. Still using a block containing 3 inactive regions, but now extended in total length from 27.5 mm to 29.5 mm, it can readily be shown that 18 unique characters (including 2 palindromes) can be coded. This extended scheme provides increased data capacity for a given overall tag length compared to the simpler scheme, at the expense of requiring data to be converted to a hexadecimal rather than decimal format.

It is also possible to use variations in the lengths of active elements instead of in the gap sizes to encode data in a generally analogous way, though this has to take account of the constraints on the minimum length for an active element discussed earlier. A coding arrangement which uses a combination of varying gap sizes and varying active region lengths is potentially efficient in terms of minimising overall tag length for a given data capacity.

CLAIMS:

1. A magnetic marker or tag which comprises (a) a first magnetic material characterised by high permeability, low coercivity and a non-linear B-H characteristic; and (b) a second magnetic material which is capable of being permanently magnetised, said first and second magnetic materials being superimposed one on the other.
2. A magnetic marker or tag which comprises (a) a first magnetic material characterised by high permeability, low coercivity and a non-linear B-H characteristic; and (b) a second magnetic material which is capable of being permanently magnetised, said first and second magnetic materials being superimposed one on the other, wherein selected regions of said second magnetic material carry magnetisation such as to magnetically divide the first magnetic material into a series of magnetically discrete zones, the length of said magnetically discrete zones and/or the lengths of said magnetised regions ("gaps") of said second material constituting elements of a code.
3. A tag as claimed in claim 1 or 2, characterised in that the two magnetic materials are substantially coterminous.
4. A tag as claimed in claim 1, 2 or 3, characterised in that the second magnetic material is a material of medium coercivity.
5. A tag as claimed in claim 1, 2, 3 or 4, characterised in that (i) the lengths of the magnetically discrete zones in said first magnetic material ("active regions") are constant and (ii) the

lengths of said magnetised regions ("gaps") of said second material are varied to provide encoding of data.

6. A tag as claimed in claim 4 or 5, characterised in that the magnetisation of said second magnetic material (in said "gaps") is uniform when the length of a given "gap" is small in relation to the minimum length of an "active region" capable of being detected when the tag is read.
- 10 7. A tag as claimed in claim 4 or 5, characterised in that, when the length, l_g , of a given "gap" is of the same order as or is larger than the minimum length, L_a , of an "active region" capable of being detected when
- 15 the tag is read, the magnetisation of said second magnetic material (in said "gaps") comprises a pattern of repeatedly reversing polarity, the spatial frequency of said pattern being such that the North and South poles thereof are spaced apart by a distance, d , which
- 20 is less than L_a .
8. A tag as claimed in claim 7, characterised in that the distance d is less than $L_a/2$.
- 25 9. A tag as claimed in claim 7 or 8, characterised in that the magnetisation of said second magnetic material (in said "gaps") comprises a pattern of repeatedly reversing polarity in the form of a sine wave which begins and ends at a 90 degree phase point in the wave.
- 30 10. A tag as claimed in any preceding claim, characterised in that said second magnetic material is in the form of commercially available magnetic recording tape.
- 35 11. A method of encoding data in a magnetic tag of the

type claimed in claim 1, which method comprises recording a magnetic pattern in selected regions of said second magnetic material, whereby said selected regions of said second magnetic material carry
5 magnetisation such as to magnetically divide the first magnetic material into a series of magnetically discrete zones, the length of said magnetically discrete zones and/or the lengths of said magnetised regions ("gaps") of said second material constituting
10 elements of a code.

12. A method according to claim 11, characterised in that said magnetic pattern is recorded using a magnetic recording head.

15

13. A method according to claim 11, characterised in that said magnetic pattern is recorded using an array of closely spaced, parallel permanent magnets.

Regions A and B are guard bands to establish a similar magnetic environment for all active regions

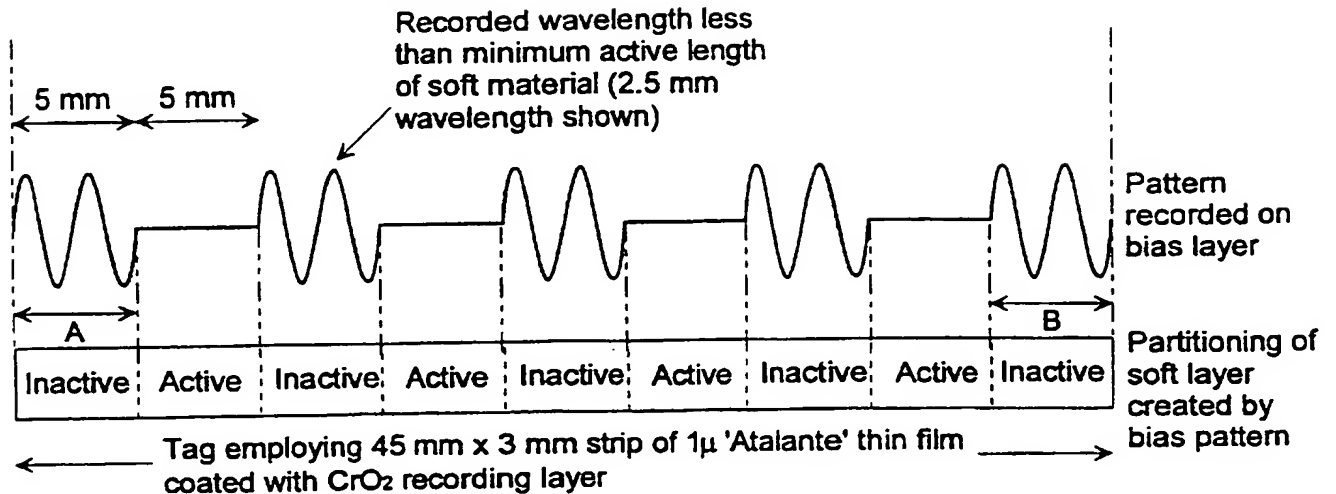


Fig 1: Example of recorded pattern to magnetically partition 45mm strip tag into 4 active segments



Fig 2: Example of practical pattern with improved definition of ends of active material segments



Fig 3: Alternative to pattern of Fig 2 with reduced field variation over active segments

INTERNATIONAL SEARCH REPORT

International Application No

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01V15/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	see column 2, line 50 - column 3, line 8 see column 4, line 11 - line 22; figures 1, 2, 5	10, 12

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
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